TRUCK PIVOT JOINT BEARING AND METHOD OF LUBRICATING

FIELD OF THE INVENTION

The present invention relates to bearing assemblies, and more particularly to bearing assemblies having two bearing members movable relative to one another and methods of lubricating these assemblies.

BACKGROUND OF THE INVENTION

Various bearing assemblies and methods of lubricating these assemblies can be found in many applications. Typical bearing assemblies include a pair of bearing members that are movable relative to one another. More specifically, a bearing or bushing is typically a cylindrical shell, with or without a flange, installed in a structural housing in conjunction with a mating shaft, pin, or bolt. Bearings having pinned joints typically are used for cyclic and oscillatory motion, such as used in landing gear joints, control surface hinge points, and actuating linkages.

The advantages of bearings are numerous. Bearings are relatively economical replacement elements which extend the useful life of major structural elements by providing protection from wear, corrosion, deformation, and other service-limiting or failure-initiating damage. The two basic considerations for successful service performance of a bearing are strength and life. Strength is the capability of the bearing to resist deformation and structural failure under static load. The life of the bearing is determined by its ability to resist wear, fretting, galling, and seizure under cyclic or oscillating motion.

Figure 1A shows a typical bearing structure assembly **100**, wherein grease **106**, such as Royal MS 11 manufactured by Royal Lubricants, Inc. of East Hanover, New Jersey, is applied between bearing assembly members comprising a bearing **101** and pin **103** to lubricate the members as they move relative to one another. Specifically, the grease **106** is disposed between the inner surface **102** of the bearing **101** and the outer

surface **104** of the pin **103**. While grease is suitable for many applications, extreme pressure and movement by the bearing assembly members may cause the grease to lose its lubricity, which may lead to overheating and eventual failure of the bearing assembly and surrounding structures.

One application where this may occur is on a landing gear apparatus of an aircraft, and more particularly on a truck pivot joint bearing assemblies for an aircraft landing gear. The bearing assemblies used in this type of application typically include a relatively thick coating of grease between the moving surfaces of the bearing. This is acceptable for most circumstances because the dynamic bearing pressures and sliding velocities of the moving surfaces are relatively low. However, rough landing conditions, such as runways with deep cracks, crevices, potholes, and/or uneven surfaces, can cause excessive use of and wear on the truck pivot joint bearing assemblies from the rapid shocks and extreme oscillations these surface abnormalities transfer to the bearing assemblies. In some cases, it has been discovered that these rough conditions create as much as ten (10) times more energy than is generated under normal conditions. This additional energy is absorbed as heat by the bearing assemblies, which accounts for the damage that occurs when using conventional bearing assemblies in these environments. As a result, the high temperatures generated in these conditions cause the grease packed between the moving surfaces of the bearing assemblies to melt away and thus lose its effective lubricity. This is shown in Figure 1B, wherein the grease **106** is no longer occupying the entire space between the opposing bearing members **101**, **103**, which allows the inner surface **102** of the bearing **101** to have intimate contact with the outer surface **104** of the pin **103**.

As the grease loses lubricity and the surfaces **102**, **104** of the bearing assembly **100** begin to directly move against each other, severe damage or failure of the bearing assembly components is likely. To prevent failure of the bearing assembly, time-consuming maintenance must be performed more frequently, which further adds to the cost of maintaining the aircraft in addition to the lost profits while the aircraft is under maintenance or repairs. Thus, it is desirable to provide a lubricant to bearing components that is more resistant to dynamic bearing pressures and heat generation in extreme conditions.

Figure 2A shows another type of conventional bearing assembly. In particular, the bearing assembly **110** includes a bearing **111** and a pin **113** having opposing surfaces **112** and **114**, respectively. A dry, greaseless coating material **116** is applied to a desired surface by spraying or coating the surface, such as the inner surface **114** of the bearing **111**. The greaseless, self-lubricating material **116** occupies the space between the opposing bearing surfaces **112, 114** such that the surfaces are only separated by the greaseless material. One example of a greaseless self-lubricating material **116** is a polyester, thermosetting, resin-based material incorporating polytetrafluoroethylene or Teflon® particles, such as the material manufactured under the name KAron by Kamatics Corporation of Bloomfield, Connecticut. This type of material is proclaimed as self-lubricating, meaning no external grease is required to lubricate the bearing assembly **110**. Indeed, greaseless lubricants such as shown in Figure 2 were designed to overcome the disadvantages of grease lubricants shown in Figure 1, particularly in terms of load capacity and service life. Other types of greaseless lubricants are described in U.S. Patent Nos. 3,929,396 and 3,996,143.

In particular, greaseless, self-lubricating materials operate at lower friction levels, which reduces the heat generated during operation. If heat does build up, the polytetrafluoroethylene particles typically expand more rapidly than the underlying surfaces to fill the space between the bearing surfaces, so that frictional contact between bearing surfaces **112, 114** is thwarted or delayed, at least temporarily. Conventional practice teaches that a thicker coating of the greaseless material **116** will provide more lubrication for the bearing **110**. While true for most applications, the extreme loading conditions mentioned above may cause the greaseless material to break down. And because the greaseless material **116** allows the bearing surfaces **112, 114** to be essentially in contact with each other separated only by the greaseless lubricant, any reduction in the thickness of the greaseless lubricant can reopen the space between the bearing surfaces, which can damage the bearing or cause the bearing to fail. This is shown in Figure 2A, wherein the greaseless material **116** has worn down in certain areas, which allows unwanted and damaging rattling or movement between the bearing assembly members **111, 113**. Thus, while greaseless lubricants provide advantageous qualities over grease lubricants, there is a need to provide a bearing assembly having a lubricant that offers

even better wear and heat resistance, which leads to longer operational life of the bearing. There is also a need to provide a bearing assembly having a lubricant that is resistant to extreme loading conditions, such that the lubricant provides longer protection to the bearing in these environments compared to protection from conventional lubricants before service is required.

SUMMARY OF THE INVENTION

These and other needs are provided, according to the present invention, by a bearing assembly that combines the benefits of greaseless lubricant materials and traditional grease lubricants to provide longer bearing lubrication and protection compared to conventional bearings and methods of lubricating the bearings. The bearing assembly of the present invention has been shown to provide up to 600% longer life than conventional grease-lubricated bearings under certain operating conditions, which greatly reduces the maintenance cost and frequency of the bearing.

In particular, the bearing assembly of the present invention comprises a pair of bearing members that are movable relative to one another. The members are typically metal, although other materials may also be used. In one embodiment, at least one of the members is formed of an aluminum, nickel, and bronze alloy, which is preferable because it has shown to be very durable and highly resistant to wear. In addition, the members are spaced a slight distance apart to define a space therebetween, such as between 0.006-0.008 inch. At least one of the bearing members has a bearing surface having a relatively thin coating of a self-lubricating, greaseless, polytetrafluoroethylene-based material thereupon. The coating, which according to one embodiment is about 0.003-0.007 inch, can be applied one of many ways, including spraying, coating, or dipping.

The thin coating of greaseless material does not occupy the entire space between the pair of bearing members. The remaining space is instead occupied by a grease lubricant. Accordingly, the grease lubricant and the greaseless lubricant act in conjunction with one another to lubricate the bearing members. Advantageously, it has been discovered that, despite the teachings that greaseless lubricant materials are not to be used in conjunction with grease lubricants, a dramatic improvement in bearing and lubrication life is realized by combining a relatively thin layer or coating of greaseless lubricant with a grease lubricant in the space defined by the bearing members.

The bearing assembly of the present invention is particularly advantageous for use in extreme conditions, such as where the bearing assembly is subjected to great dynamic pressures and oscillations. For example, truck pivot joint bearing assemblies used in aircraft landing gear are prime candidates for employing the teachings of the bearing assembly of the present invention, as truck pivot joint bearing assemblies may encounter great dynamic pressures and oscillations during landing cycles. Of course, the bearing assembly of the present invention can also be used in many other applications where the loading conditions are not extreme, as the longer lubrication and bearing life is appreciable in a broad range of applications.

Thus, the present invention provides a bearing assembly having an improved bearing life and requiring less frequent maintenance cycles to the bearing components. By combining the thin layer of greaseless material with a grease lubricant in the space defined between the two bearing members, at least two advantages are realized. First, the thin layer or coating of greaseless material provides a lower coefficient of friction compared to grease lubricants, which delays the onset of heat buildup and loss of lubricity. Second, the grease lubricant provides a less-rigid material for moving about and occupying the space between the bearing members, which further improves bearing life.

By contrast, using only a greaseless coating (i.e., a relatively thick coating as taught by conventional bearings) between the bearing members can result in unwanted play between the surfaces of the bearing assembly as the coating wears away. By using a relatively thin greaseless coating in conjunction with a grease lubricant, the greaseless lubricant receives little or no contact with the opposing bearing surface and thus wears more slowly. In addition, the grease lubricant fills the space between the bearing assembly surfaces to prevent unwanted movement or play. And because the thin greaseless coating reduces the friction and heat generated during loading cycles, the grease lubricant's life span is increased. Thus, the bearing assembly of the present invention provides a clear advantage over conventional bearing assemblies and lubrication techniques.

BRIEF DESCRIPTION OF THE DRAWINGS

Having thus described the invention in general terms, reference will now be made to the accompanying drawings, which are not necessarily drawn to scale, and wherein:

Figures 1A and 1B are cross-sectional views of a bearing assembly according to the prior art;

Figures 2A and 2B are cross-sectional views of a bearing assembly according to the prior art;

Figure 3 is a side view of a landing gear assembly for an aircraft according to one embodiment of the present invention;

Figure 4 is a cross-sectional view of a truck pivot joint bearing of the landing gear assembly as viewed along line 4-4 of Figure 3;

Figure 5 is a side perspective view of a truck pivot bushing according to one embodiment of the present invention;

Figure 6 is a cross-sectional view of a truck assembly according to one embodiment of the present invention; and

Figure 7 is a cross-sectional view of a bearing assembly as viewed along line 7-7 of Figure 4.

DETAILED DESCRIPTION OF THE INVENTION

The present invention now will be described more fully hereinafter with reference to the accompanying drawings, in which preferred embodiments of the invention are shown. This invention may, however, be embodied in many different forms and should not be construed as limited to the embodiments set forth herein; rather, these embodiments are provided so that this disclosure will be thorough and complete, and will fully convey the scope of the invention to those skilled in the art. Like numbers refer to like elements throughout.

Figures 3-6 show various views of portions of a landing gear assembly **10** for an aircraft, such as a Boeing 757. The landing gear assembly **10** includes at least one shock strut **12** that is rotatably connected to a truck pivot pin **24**. Specifically, the shock strut **12** defines an opening for rotatably receiving the truck pivot pin **24**. The shock strut **12** also includes a distal portion called an inner cylinder fork **26** that extends away from the

opening. The landing gear assembly **10** also includes a truck pivot bearing assembly, shown generally as **20**. The bearing assembly **20** includes a truck assembly **14** that is rotatably connected to the truck pivot pin **24**, and at least two pairs of wheels **16** are attached to the truck assembly **14**.

Figures 4 and 6 show cross sectional views of the bearing **20**, wherein Figure 6 is a cross sectional view of the truck assembly **14** forming part of the bearing **20** shown in Figure 4. As shown in Figure 6, the truck assembly **14** defines a cavity **34** therethrough having an inner surface **31**. The truck assembly **14** is preferably formed of metal, such as a high strength steel alloy, although other metals or materials may also be used, such as titanium. The truck pivot pin **24**, which in one embodiment is a chrome plated pin, extends through the cavity **34** of the truck assembly **14**. A pair of truck pivot bushings **30** are positioned at opposing ends of the truck assembly **14** such that flanged surfaces **33** of the pivot bushings engage sidewalls **23** of the truck assembly. In addition, a pair of back-to-back inner cylinder pivot bushings **40** are positioned proximate the inner cylinder forks **26** such that the inner cylinder assemblies are separated from the truck assembly **14** by the pivot bushing **30** and the inner cylinder pivot bushings **40.** In this regard, the truck pivot bushings **30** and inner cylinder pivot bushings **40** provide low-friction support to the truck pivot pin **24** as it rotates inside the truck assembly **14** and shock struts **12**. A splined washer **28** helps secure the inner cylinder pivot bushings **40** about the pivot pin **24**, and multiple pairs of brake rods **42** extend substantially parallel to the truck assembly **14**.

As shown in Figure 4, the pivot bushings **30** are interposed between the truck assembly **14** and the truck pivot pin **24**. As shown in Figure 5, each pivot bushing **30** is generally tubular, and preferably defines a plurality of lubrication distribution grooves **36** that receive and distribute grease between the truck pivot pin **24** and the pivot bushings **30** so that the pivot pin **24** is rotatable relative to the truck assembly **14**. Each pivot bushing **30** also includes an outer surface **32** that is positioned proximate the inner surface **31** of the truck assembly **14** in a press-fit or interference fit so that the pivot bushing **30** does not move relative to the truck assembly **14**. A seal **38** is disposed proximate the lubrication distribution grooves **36** such that grease or other lubricant is prevented from escaping. According to one embodiment, the seal **38** is formed from an

elastomer, although other materials could also be used to form the seal. As shown, each pivot bushing **30** engages a sidewall **23** of the truck assembly **14** and an adjacent inner cylinder pivot bushing **40** to further seal the pivot bushing and the truck assembly **14**.

Figure 7 shows a detailed cross-sectional view of the truck assembly **14**, pivot bushing **30**, and pivot pin **24** according to a preferred embodiment of the present invention. In particular, the pivot bushing **30** is disposed radially inwardly of the truck assembly **14** and is secured thereto by a frictional interference fit. The inner surface **35** of the pivot bushing **30** is proximate the pivot pin **24**, and an advantageous lubricant according to the present invention is interposed therebetween. According to one embodiment, the inner surface **35** of the pivot bushing **30** is coated with a greaseless, self-lubricating material **50**. It is also possible to apply the relatively thin coating of greaseless material **50** on both the inner surface **35** of the pivot bushing **30** and the outer surface of the pivot pin **24**. Alternatively, only the outer surface of the pivot pin **24** may be coated with the greaseless material **50**, although preferably only the inner surface **35** of the pivot bushing **30** includes the greaseless material **50**. The material **50** is preferably a polytetrafluoroethylene-based material, such as a material sold under the trade name KARON by Kamatics Corporation of Bloomfield, Connecticut. The greaseless material **50** can be applied to the inner surface **35** of the pivot bushing **30** in a number of ways, such as spraying, brushing on, or by dipping the pivot bushing **30** in a bath of the greaseless material. The greaseless material **50** includes a solid particulate, such as Teflon®, that is embedded in a stabilizer material in the form of flocked, powdered, fibrous, flaked, beaded, or other forms. Other particulate materials may also be used, such as silver powder, lead powder, and the like. The greaseless material **50** has a thickness of about 0.003-0.007 inch, and preferably about 0.005 inch. As shown in Figure 7, the thickness of the greaseless material **50** is not enough to substantially fill the space defined by the pivot bushing **30** and the pivot pin **24**.

Advantageously, the space defined by the pivot bushing **30** and the pivot pin **24** not occupied by the greaseless material **50** is occupied or filled by a grease lubricant **58**, such as an extreme pressure grease sold under the name Royco 11MS manufactured by Royal Lubricants, Inc. of East Hanover, New Jersey. Other types of greases may also be used, such as any extreme pressure grease that is apparent to one of skill in the art. The

chosen grease must be highly resistant to extreme dynamic bearing pressures and temperatures.

The combination of a relatively thin coating of the greaseless material **50** coupled with the grease lubricant **58** as disclosed by the present invention flies in the face of conventional lubrication systems and methods. In this regard, it has been discovered that applying a relatively thin coating, such as about 0.005 inch, of the greaseless material **50** in combination with the grease lubricant that fills the remainder of the gap between the pivot bushing **30** and the pivot pin **24** allows dynamic bearing pressures to be increased dramatically to a level that approaches the allowable pressures for the base bearing material. More particularly, the relatively thin layer or coating of greaseless material **50** has a friction coefficient of only about 0.08, whereas grease lubricants have a friction coefficient of about 0.20. As discussed above, conventional applications of greaseless material coatings call for much thicker coatings, which has been discovered to limit their use at relatively low dynamic bearing pressures and sliding velocities. Accordingly, the bearing assembly **20** according to the present invention can operate longer under extreme conditions, such as when landing aircraft on very rough runways where the bearing receives severe oscillations and sliding velocities. Specifically, the bearing assembly **20** according to the present invention reduces the friction-generated heat sufficiently to substantially reduce or eliminate damage to the truck assembly **14** or inner cylinder assembly **26**.

Another advantage of the bearing assembly **20** according to the present invention is that the combination of greaseless, self-lubricating material **50** and the grease lubricant **58** can be applied in existing bearing assemblies, such as those found in aircraft landing gear assemblies, without having to redesign the assemblies to handle the extreme conditions. Thus, existing aircraft landing gear can easily be retrofitted with the bearing assembly **20** of the present invention, which is significantly less expensive than redesigning a new type of landing gear assembly or bearing configuration. In addition, the bearing assembly **20** of the present invention requires less frequent maintenance compared to conventional bearings operating under similar conditions, which substantially reduces maintenance man hours, downtime, and overall operating costs. In fact, it has been discovered that up to a 600% improvement in life span is achieved in

comparison to conventional grease-lubricated bearings by applying the bearing assembly **20** of the present invention to truck pivot joint bearings in large jet aircraft landing gear assemblies.

Many modifications and other embodiments of the invention will come to mind to one skilled in the art to which this invention pertains having the benefit of the teachings presented in the foregoing descriptions and the associated drawings. Therefore, it is to be understood that the invention is not to be limited to the specific embodiments disclosed and that modifications and other embodiments are intended to be included within the scope of the appended claims. For example, the teachings of the present invention, namely a bearing assembly **20** having the relatively thin coating **50** of greaseless, self-lubricating material in combination with a grease lubricant **58** used in combination in the space defined between the inner and outer members of a bearing assembly, can be applied to many industries in addition to the aerospace industry where lower friction bearings are desired. In addition, the teachings of the present invention regarding the combination of a greaseless, self-lubricating material used in combination with a grease lubricant could be applied to a broad range of applications, including applying the combination to a nut and bolt combination, or similar applications. Although specific terms are employed herein, they are used in a generic and descriptive sense only and not for purposes of limitation.